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Roth et al.

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(54) **DIRECTLY COMMUNICATED
TURBOCHARGER**

25/071 (2013.01); *F02M 25/0707* (2013.01);
F02M 25/0711 (2013.01); *F02M 25/0727*
(2013.01);

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F02F 1/24
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123/559.1, 562, 568.13, 193.5
See application file for complete search history.

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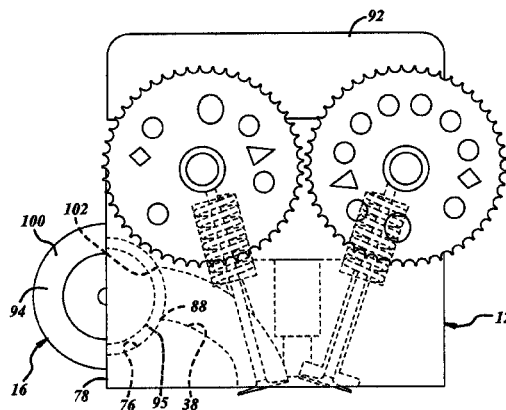
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(57)

ABSTRACT

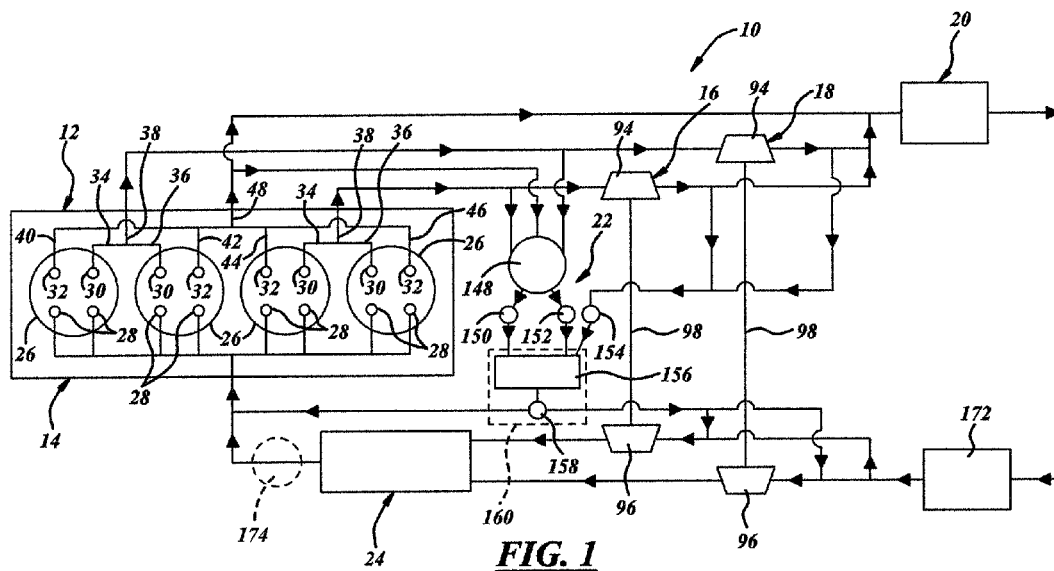
One illustrative embodiment includes a turbocharger (16, 18) with a turbine (94) and a compressor (96). The turbine (94) has an inlet passage (114) which may directly communicate with a blowdown exhaust passage (34, 36, 38) of a cylinder head (12) of an internal combustion engine (14). The inlet passage (114) may directly receive exhaust gas from the blowdown exhaust passage (34, 36, 38).

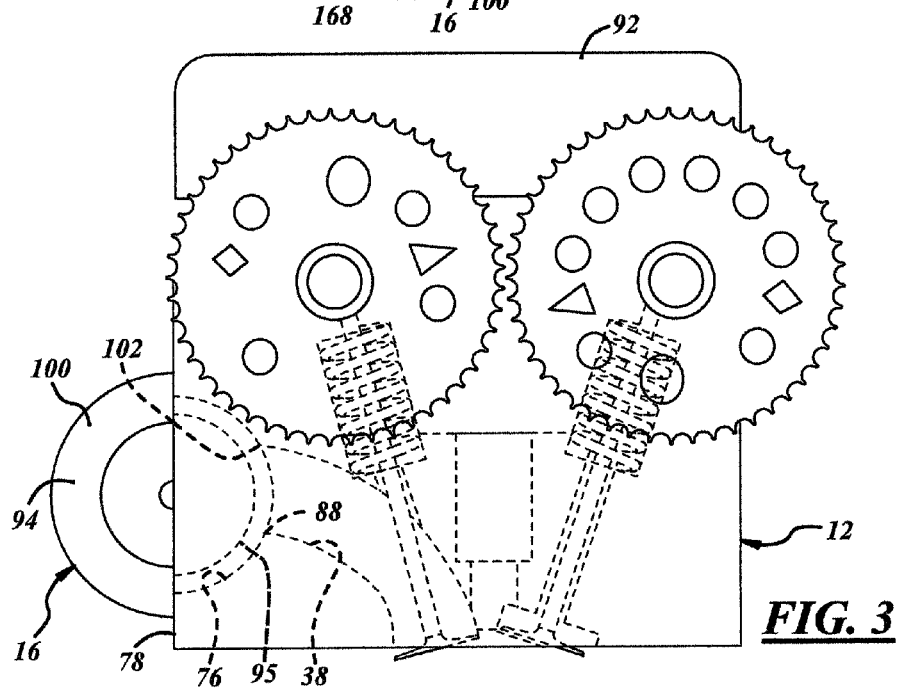
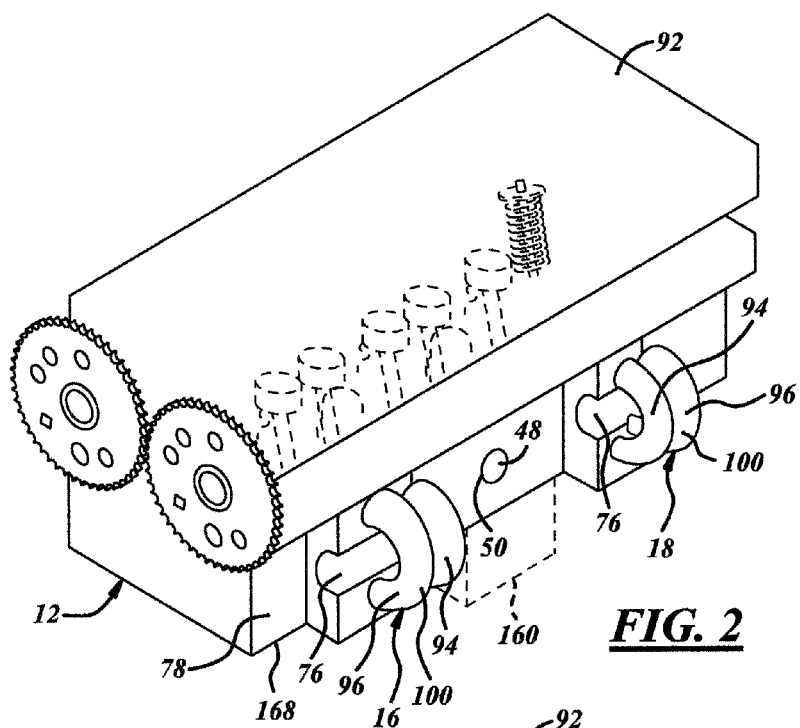
12 Claims, 6 Drawing Sheets

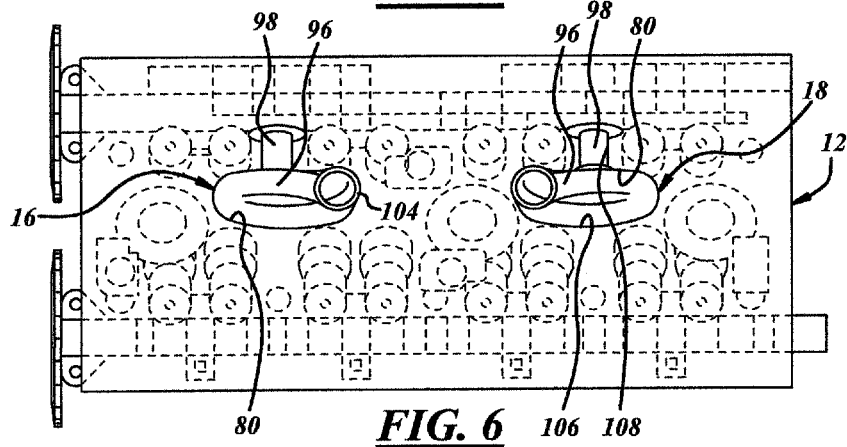
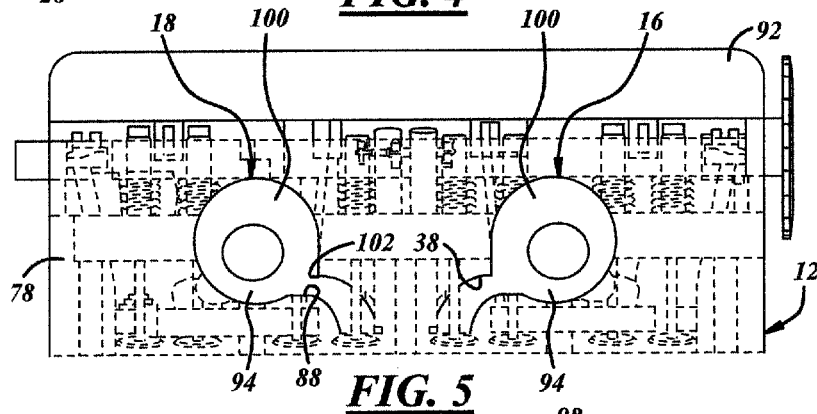
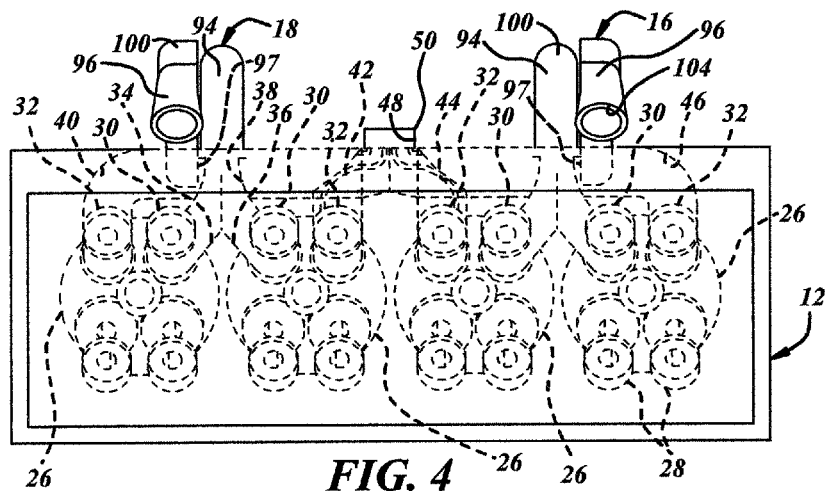


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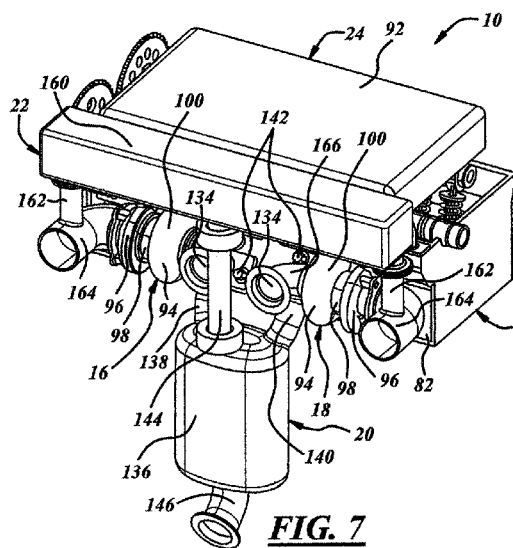


FIG. 7

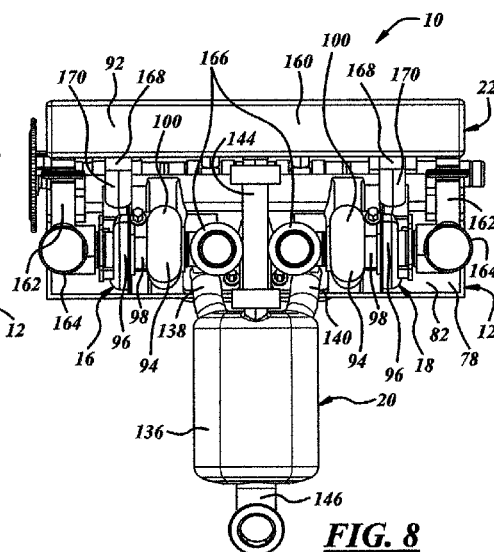


FIG. 8

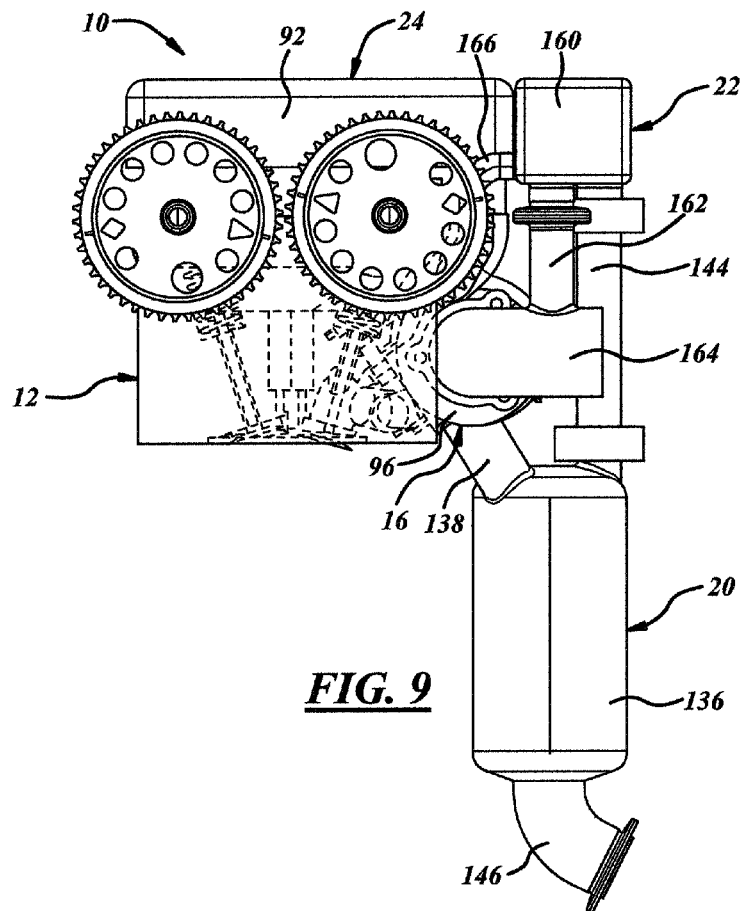


FIG. 9

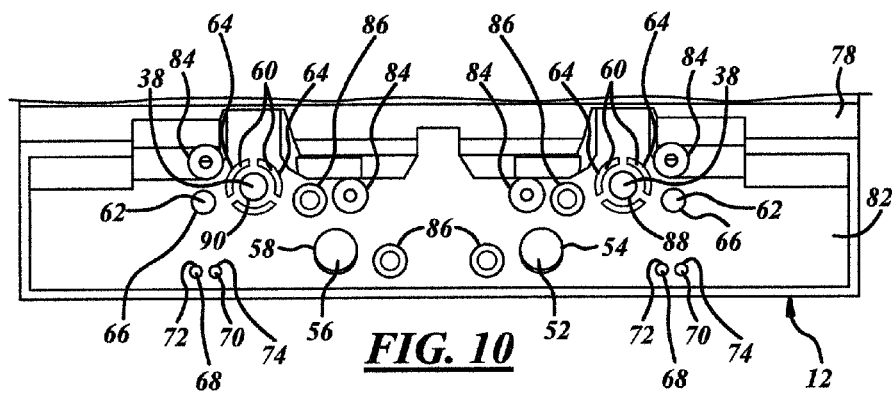
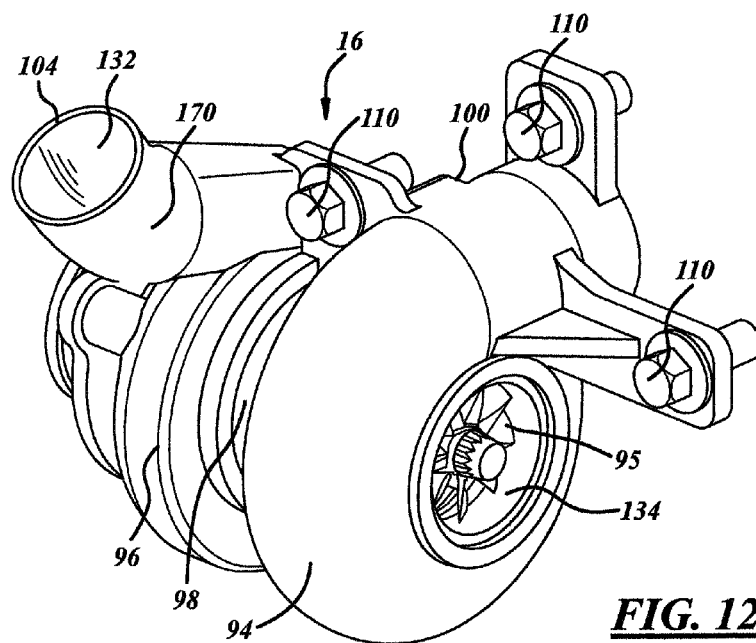
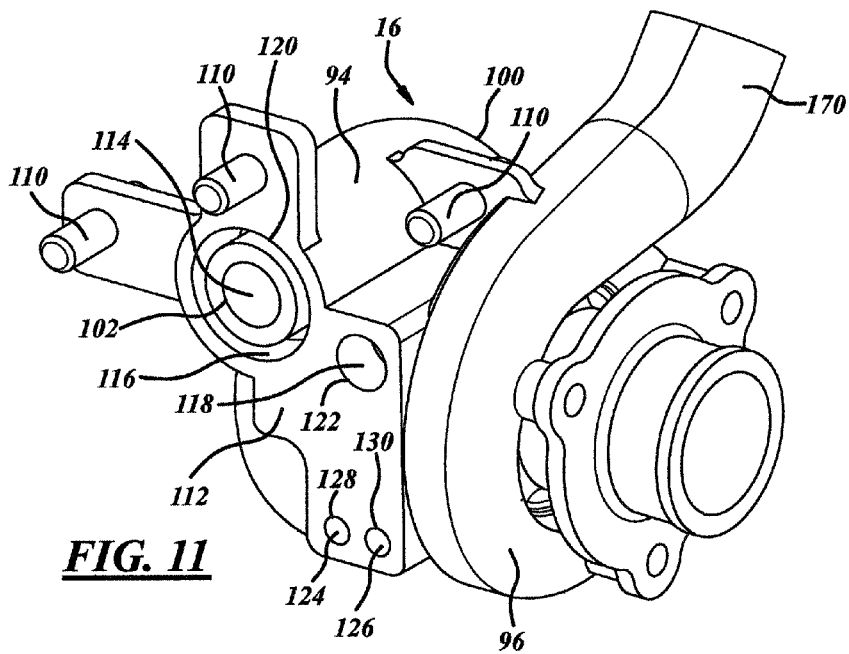


FIG. 10



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**DIRECTLY COMMUNICATED
TURBOCHARGER****CROSS-REFERENCE TO RELATED
APPLICATIONS**

This application claims the benefit of U.S. Provisional Application No. 61/297,422, filed Jan. 22, 2010.

TECHNICAL FIELD

The technical field generally relates to internal combustion engines, turbochargers, and other components of an internal combustion engine breathing system.

BACKGROUND

Internal combustion engines are often equipped with internal combustion engine breathing systems to decrease emissions and increase engine efficiency. The breathing systems may include one or more turbochargers, one or more exhaust gas recirculation (EGR) assemblies, and other components. Valves and passages are commonly located throughout the breathing systems to regulate fluid-flow between the breathing system components.

**SUMMARY OF ILLUSTRATIVE
EMBODIMENTS OF THE INVENTION**

One illustrative embodiment includes a product which may include a turbocharger. The turbocharger may include a turbine and a compressor. The turbine may have an inlet passage that may directly communicate with a blowdown exhaust passage of a cylinder head of an internal combustion engine and that may directly receive exhaust gas from the blowdown exhaust passage.

One illustrative embodiment includes a product which may include a cylinder head and a turbocharger. The cylinder head may have two or more cylinders. Each of the cylinders may have a blowdown exhaust passage and a scavenge exhaust passage. In the example of two cylinders and two blowdown exhaust passages, the two blowdown exhaust passages may converge toward each other into a single blowdown exhaust passage and may communicate with each other inside of the body of the cylinder head. The cylinder head may also have one or more passages. The turbocharger may have an inlet passage that may directly communicate with the single blowdown exhaust passage at a location that is downstream of the location where the two blowdown exhaust passages converged with each other. The inlet passage may directly receive exhaust gas from the single blowdown exhaust passage. The turbocharger may also have one or more passages that may directly communicate with the one or more passages of the cylinder head.

One illustrative embodiment includes a product which may include an internal combustion engine breathing system. The internal combustion engine breathing system may include a turbocharger, an aftertreatment device, an exhaust gas recirculation assembly, and a charge-air cooler. The turbocharger may include a turbine and a compressor. The turbine may have an inlet passage that may directly communicate with a blowdown exhaust passage of a cylinder head of an internal combustion engine. The inlet passage may also directly receive exhaust gas from the blowdown exhaust passage. The turbocharger may have numerous passages that may directly communicate with ports, passages, or both of the cylinder head. The aftertreatment device may communicate with a

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scavenge exhaust passage of the cylinder head and may receive exhaust gas from the scavenge exhaust passage. The exhaust gas recirculation assembly may communicate with the scavenge exhaust passage and may receive exhaust gas from the scavenge exhaust passage. The exhaust gas recirculation assembly may also communicate with the compressor. The charge-air cooler may be mounted to a cover of the cylinder head and may communicate with the compressor.

Other illustrative embodiments of the invention will become apparent from the detailed description provided hereinafter. It should be understood that the detailed description and specific examples, while disclosing illustrative embodiments of the invention, are intended for purposes of illustration only and are not intended to limit the scope of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

Illustrative embodiments of the present invention will become more fully understood from the detailed description and the accompanying drawings, wherein:

FIG. 1 is a schematic of an illustrative embodiment of an internal combustion engine cylinder head and of an internal combustion engine breathing system.

FIG. 2 is a schematic perspective view of an illustrative embodiment of an internal combustion engine cylinder head and of a pair of turbochargers.

FIG. 3 is a side view of the cylinder head and turbochargers of FIG. 2.

FIG. 4 is top view of the cylinder head and turbochargers of FIG. 2.

FIG. 5 is a schematic side view of an illustrative embodiment of an internal combustion engine cylinder head and of a pair of turbochargers.

FIG. 6 is top view of the cylinder head and turbochargers of FIG. 5.

FIG. 7 is a perspective view of an illustrative embodiment of an internal combustion engine cylinder head, of a pair of turbochargers, of a catalytic converter, of an exhaust gas recirculation assembly, and of a charge-air cooler.

FIG. 8 is a front view of the components of FIG. 7.

FIG. 9 is a side view of the components of FIG. 7.

FIG. 10 is a close-up cut-away view of the internal combustion engine cylinder head of FIG. 7, with components removed in order to show an illustrative embodiment of various passages and ports of the internal combustion engine cylinder head.

FIG. 11 is a perspective rear view of one of the turbochargers of FIG. 7.

FIG. 12 is a perspective front view of the turbocharger of FIG. 11.

**DETAILED DESCRIPTION OF ILLUSTRATIVE
EMBODIMENTS**

The following description of the embodiment(s) is merely exemplary (illustrative) in nature and is in no way intended to limit the invention, its application, or uses.

The figures illustrate several illustrative embodiments of an internal combustion engine (ICE) breathing system 10 that may include, among other components, a cylinder head 12 of an internal combustion engine (ICE) 14, a pair of turbochargers 16, 18, an exhaust gas aftertreatment device 20, an exhaust gas recirculation (EGR) subsystem or assembly 22, and a charge-air cooler 24. One or more of the components 12, 16, 18, 20, 22, and 24 may be designed for an integrated and compact construction of the ICE breathing system 10. This

construction may generally minimize packaging and minimize cost. Among other things, the construction may also, though need not, increase turbocharger efficiency, increase turbocharger boost capability, eliminate the need for a turbocharger wastegate, and reduce the related pumping mean effective pressure (PMEP).

The ICE breathing system **10** may be used with the internal combustion engine **14** in order to manage fluid-flow delivered to the engine and expelled from the engine, and in order to decrease exhaust emissions and increase overall engine efficiency. The ICE breathing system **10** may have various arrangements and various engine breathing system components. The example arrangement of FIG. **1** is meant only to show some of the fluid-flow relationship possibilities among and between components of the ICE breathing system **10**, and does not necessarily indicate direct or indirect connections or passages among and between the components. Other arrangements may exist and may depend on many factors including the architecture and type of the ICE **14**; for example, blowdown exhaust ports may communicate with a proportional valve at a single inlet instead of at a pair of separate inlets as shown in FIG. **1**.

The cylinder head **12** may be located above cylinder bores and pistons of the ICE **14** and may accommodate installation of spark plugs, fuel injectors, exhaust valves, intake valves, and/or a camshaft or other valve actuation mechanism; the exact design of the cylinder head **12** may depend on many factors including the architecture and type of the ICE and the component construction and component arrangement such as turbocharger construction and arrangement and EGR assembly construction and arrangement. In the example of FIGS. **2-4**, the cylinder head **12** may include four cylinders **26** arranged in-line. Each cylinder **26** may have a pair of intake valves **28**, a blowdown exhaust valve **30**, and a scavenge exhaust valve **32** (shown in phantom as poppet valves). The cylinder head **12** may be designed for divided exhaust gas flow—that is, blowdown and scavenge exhaust gas flow. Neighboring cylinders **26** may have blowdown exhaust passages that converge toward each other into a single and common blowdown exhaust passage before exiting the body of the cylinder head **12**; for example, referring to FIG. **4**, a first blowdown exhaust passage **34** and a second blowdown exhaust passage **36** may converge into a single blowdown exhaust passage **38**. The exhaust gas from the first and second blowdown exhaust passages **34**, **36** may come together and communicate at the single blowdown exhaust passage **38**. The other neighboring cylinders **26** may have a similar construction so that there is a pair of single blowdown exhaust passages **38**, and in other embodiments more than two blowdown exhaust passages can come together into a single blowdown exhaust passage. In still other embodiments, the blowdown exhaust passages need not converge toward each other.

Still referring to FIG. **4**, the cylinders **26** may have scavenge exhaust passages that may converge toward one another into a single and common scavenge exhaust passage before exiting the body of the cylinder head **12**; for example, a first scavenge exhaust passage **40**, a second scavenge exhaust passage **42**, a third scavenge exhaust passage **44**, and a fourth scavenge exhaust passage **46** may converge into a single scavenge exhaust passage **48**. The exhaust gas from the scavenge exhaust passages **40**, **42**, **44**, and **46** may come together and communicate at the single scavenge exhaust passage **48**, and may exit the cylinder head **12** at a single scavenge port opening **50**. In other embodiments, such as that shown in FIG. **10**, the first and second scavenge exhaust passages **40**, **42** may converge into a first single scavenge exhaust passage **52** with a first single scavenge port opening **54**, and the third and

fourth scavenge exhaust passages **44**, **46** may converge into a second single scavenge exhaust passage **56** with a second single scavenge port opening **58**.

The cylinder head **12** may also have various passages routed throughout its body in order to carry various fluids therethrough. For example, referring still to FIG. **10**, a coolant passage supply **60** and a coolant passage return **62** may be provided in the cylinder head **12** for coolant flow in the cylinder head and in the turbochargers **16**, **18**, as will be subsequently described. The coolant passage supply **60** may have one or more coolant supply openings **64**, and the coolant passage return **62** may have one or more coolant return openings **66**. Also, an oil passage supply **68** and an oil passage return **70** may be provided in the cylinder head **12** for oil and/or lubrication flow in the cylinder head and in the turbochargers **16**, **18**. The oil passage supply **68** may have one or more oil supply openings **72**, and the oil passage return **70** may have one or more oil return openings **74**.

The cylinder head **12** may have different constructions and/or components than the constructions and components already described. In the embodiment of FIGS. **2-4**, the cylinder head **12** may have a cavity **76** located in a side wall **78** of the body of the cylinder head. The cavity **76** may be structured to cradle and support components of one of the turbochargers **16**, **18**; for example, the cavity may have a portion structured to support a turbine wheel **95**, another portion structured to support a compressor wheel **97**, and yet another portion structured to support a shaft assembly. In the embodiment of FIGS. **5** and **6**, the cylinder head **12** may have an internal cavity **80** located inside the body of the cylinder head. The internal cavity **80** may be structured to cradle and support components of one of the turbochargers **16**, **18**; for example, the internal cavity may have a portion structured to fully support a compressor wheel, and may have another portion structured to fully or partly support a shaft assembly; indeed, the internal cavity may form part of a housing or cover of the turbochargers. And in the embodiment of FIGS. **7-10**, the cylinder head **12** may have a mounting face **82** located in the side wall **78** of the body of the cylinder head. The mounting face **82** may be a planar wall that may be recessed in the side wall **78**. In addition to the openings **64**, **66**, **72**, and **74**, one or more turbocharger mounts **84** and one or more manifold mounts **86** may be located at the mounting face **82**. Also, as alluded to, referring to FIG. **10**, blowdown exhaust gas may exit the cylinder head **12** at a first single blowdown port opening **88** and at a second single blowdown port opening **90**.

The cylinder head **12** may be equipped with any suitable valve actuation mechanism in order to actuate the intake valves **28**, actuate the blowdown exhaust valves **30**, and actuate the scavenge exhaust valves **32**, or the particular valve actuation mechanism can be provided as a separate component that is unassociated with the cylinder head **12**. The valve actuation mechanism may have variable valve timing functionality. In one example, the valve actuation mechanism may include individual actuators such as solenoids. In another example, a dual acting concentric cam device may be used to actuate the valves **28**, **30**, and **32** independently of one another. One suitable dual acting concentric cam device is disclosed in the International Application No. PCT/US09/34392 with an international filing date of Feb. 18, 2009, titled Controlling Exhaust Gas Flow Divided Between Turbocharging and Exhaust Gas Recirculating, and in the name of applicant BorgWarner Inc. In this example, the dual acting concentric cam device may be controlled by the method taught in the International Application No. PCT/US09/34392. Using that control method, or using another suitable control method,

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exhaust gas and the associated energy may be delivered to the turbochargers **16, 18** in a selective way to control turbocharger boost via valve event timing without the use of a turbine bypass, as taught in the International Application No. PCT/US09/34392. For example, opening and/or closing of the blowdown exhaust valves **30** and of the scavenge exhaust valves **32** may be advanced or retarded to manage blowdown exhaust gas flow to the turbochargers **16, 18**. In a similar way, turbocharger boost efficiency may be optimized. Of course, other suitable valve actuation mechanisms and control methods are possible.

A cover **92** may be provided in order to close the top side of the cylinder head **12**. The cover **92** may be bolt-on to the body of the cylinder head **12** and may carry or be integrated with other components, as will be subsequently described. The exact design of the cover **92** may depend on many factors including the architecture and type of the ICE **14** and the component construction and component arrangement such as turbocharger construction and arrangement and EGR assembly construction and arrangement.

The internal combustion engine **14** may combust fuel with an oxidizer (e.g., air) and may expel fluid, such as exhaust gas which may include gas, liquid, and other matter, thereafter to the ICE breathing system **10**. The ICE **14** may be a spark-ignited engine (e.g., gasoline, methanol), a diesel engine, an alternative fuel engine, or another type. The ICE **14** may be of different types having different arrangements and different numbers of cylinders (e.g., in-line, I-2, I-4, I-6, V-type, V-6, V-8, etc.). A cylinder block (not shown) may sit below the cylinder head **12** and may have cylindrical bores to accommodate reciprocating pistons. The ICE **14** may function under a four-stroke engine operating cycle with a blowdown phase and a scavenging phase. In the blowdown phase, the blowdown exhaust valves **30** may open just before the associated piston reaches a bottom dead center (BDC) position. Exhaust gas then enters the blowdown exhaust passages **34, 36** under relatively increased pressure. In the scavenging phase, the scavenge exhaust valves **32** open as the associated piston sweeps back up from the BDC position and toward a top dead center (TDC) position to displace most, if not all, of the remaining exhaust gas. The remaining exhaust gas then enters the scavenge exhaust passages **40, 42, 44, 46** under a comparatively decreased pressure. In some embodiments, an intake manifold and/or an exhaust manifold may be provided for the ICE **14**; the exhaust manifold may include a blowdown exhaust manifold and a scavenge exhaust manifold which may be provided as separate components or as a one-piece component.

The turbochargers **16, 18** may be driven by exhaust gas expelled from the ICE **14** and may force an additional amount of air or air-fuel mixture into the ICE, as may otherwise be the case, to improve engine performance. The turbochargers **16, 18** may come in various types including a fixed geometry turbocharger, a variable geometry turbocharger, a 1-stage turbocharger, a 2-stage turbocharger, or the like. The turbochargers **16, 18** may directly communicate with the cylinder head **12** and with the blowdown exhaust passage **38**, and may directly receive blowdown exhaust gas from the blowdown exhaust passage. In some cases, minimizing the total length that the exhaust gas has to travel from the exhaust valve to the turbocharger has advantages such as greater turbocharger efficiency and boost capability.

The words direct, directly, and their related forms—as used, for example, to describe the relation between the turbochargers and cylinder head—means without substantial intervening components and/or structures such as pipes, tubes, conduits, or the like. That is to say, for example, an inlet

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opening of the turbocharger may be located immediately at, and may be immediately aligned with, an outlet opening of the cylinder head, such that fluid exiting the outlet opening may immediately enter the inlet opening. Of course, seals and/or other structures may be used in order to properly facilitate this immediacy. This is in contrast to an indirect relation between a turbocharger and cylinder head in which one or more pipes, tubes, conduits, or the like are placed between the respective inlet and outlet openings.

Each of the turbochargers **16, 18** may include a turbine **94**, a compressor **96**, and a shaft assembly **98**. The turbine **94** may have a turbine wheel **95** that is driven by the exhaust gas expelled from the ICE **14**, and the compressor **96** may have a compressor wheel **97** that rotates with the turbine wheel **95** via the common shaft assembly **98**. The compressor **96** pressurizes air and other fluid that, after leaving the compressor, eventually enters the intake side of the ICE **14**. The shaft assembly **98** may include bearings, bushings, and the like that facilitate rotation between, and connection to, the turbine and compressor wheels **97**. Though not shown and not necessary in all cases, the turbine **94** and compressor **96** may each include a bypass valve and related passage, or waste gate, which divert fluid around the turbine and compressor.

The exact construction and arrangement of the turbochargers **16, 18** may differ among different embodiments, and may depend on many factors including the architecture and type of the ICE **14** and the component construction and component arrangement such as cylinder head construction and arrangement and EGR assembly construction and arrangement. For example, referring to FIGS. 2-4, each of the turbochargers **16, 18** may include a housing or cover **100**. The cover **100** may be physically connected to the cylinder head **12**, and in this embodiment may directly mount to the side wall **78** of the cylinder head by bolting or may bolt directly to a mounting face of the cylinder head. When mounted, the cover **100** and the cavity **76** together may provide the structure needed to support rotation and proper functionality of the turbochargers **16, 18**; for example, the cover may provide about one-half of the structure for the turbochargers while the cavity provides the other half. Like the cavity **76**, the cover **100** may be structured to cradle and support the turbine **94**, the compressor **96**, and the shaft assembly **98**; the cover may have a portion structured to support the turbine wheel, another portion structured to support the compressor wheel, and yet another portion structured to support the shaft assembly. These portions may be part of a unitary cover, or may be separate pieces that are connected together.

Still referring to the embodiment of FIGS. 2-4, the cover **100** may have various passages routed throughout its body in order to carry various fluids therethrough. For example, the cover **100** may have a coolant passage supply and return for coolant flow, and may have an oil passage supply and return for oil and/or lubrication flow. The coolant and oil passages of the cover **100** may directly communicate with the coolant and oil passages of the cylinder head **12**, so that together the directly communicating passages may provide a single continuously extending passage between the cover and the cylinder head. Referring in particular to FIG. 3, an inlet opening **102** of the turbine **94** may directly communicate with the first single blowdown port opening **88** of the single blowdown exhaust passage **38** (same construction and arrangement may be provided for the other turbocharger at the second single blowdown port opening **90**). Indeed, the inlet opening **102** and the first single blowdown port opening **88** may constitute the same opening, as shown in FIG. 3. The inlet opening **102** may lead to an inlet passage that may directly receive blowdown exhaust gas from the single blowdown exhaust passage

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38 and that may direct blowdown exhaust gas to the turbine wheel **95** of the turbine **94**. The inlet passage may be formed in part by the cavity **76**. Referring now to FIG. **4**, the cover **100** may have an outlet opening **104** of the compressor **96** which may communicate with the charge-air cooler **24**.

Referring to the embodiment of FIGS. **5** and **6**, the cover **100** may directly mount by bolting to the side wall **78** of the cylinder head **12**, or may bolt directly to a mounting face of the cylinder head. In this embodiment, the cover **100** may be an external structure (with respect to the cylinder head **12**) and may provide the entire structure needed to support rotation and proper functionality of the turbine **94** and part of, or all of, the shaft assembly **98**. The structure needed to support rotation and proper functionality of the compressor **96**, on the other hand, may be provided entirely by the internal cavity **80**. The internal cavity **80** may have a portion **106** structured to fully support the compressor wheel of the compressor **96**, and may have a portion **108** structured to fully or partly support the shaft assembly **98**.

The external cover **100** may have various passages routed throughout its body in order to carry various fluids therethrough. For example, the cover **100** may have a coolant passage supply and return for coolant flow, and may have an oil passage supply and return for oil and/or lubrication flow. The coolant and oil passages of the cover **100** may directly communicate with the coolant and oil passages of the cylinder head **12**, so that together the directly communicating passages may provide a single continuously extending passage between the cover and the cylinder head. Referring in particular to FIG. **5**, the inlet opening **102** of the turbine **94** may directly communicate with the first single blowdown port opening **88** of the single blowdown exhaust passage **38** (same construction and arrangement may be provided for the other turbocharger at the second single blowdown port opening **90**). Indeed, the inlet opening **102** and the first single blowdown port opening **88** may constitute the same opening, as shown in FIG. **5**. The inlet opening **102** may lead to an inlet passage that may directly receive blowdown exhaust gas from the single blowdown exhaust passage **38** and that may direct blowdown exhaust gas to the turbine wheel **95** of the turbine **94**. The inlet passage may be formed in part by the external cover **100**. Referring now to FIG. **6**, the internal cavity **80** may, in part, form the outlet opening **104** of the compressor **96** which may communicate with the charge-air cooler **24**.

Referring to the exemplary embodiment of FIGS. **7-12**, the cover or housing **100** may be directly mounted to the mounting face **82** of the cylinder head **12** via bolts **110**. In this embodiment, the housing **100** may have a mounting face **112** that may be generally planar like the mounting face **82**, and that, when mounted, may directly oppose the mounting face of the cylinder head **12** through a gap or space, or oppose the mounting face by direct contact therewith. The housing **100** may be an external structure (with respect to the cylinder head **12**), and may provide the entire structure needed to support rotation and proper functionality of the turbine **94**, the compressor **96**, and the shaft assembly **98**; for example, the turbine wheel may be wholly and completely enclosed within the housing **100**, the compressor wheel may be wholly and completely enclosed within the housing, and the shaft assembly with its shaft, bearings, bushings, and/or other components where applicable, may be wholly and completely enclosed within the housing. The housing **100** may include a turbine portion, a compressor portion, and a shaft assembly portion—all of which may be one or more separate pieces that are connected together upon assembly.

Referring to FIG. **11**, the housing **100** may have various passages routed throughout its body in order to carry various

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fluids therethrough. For example, the housing **100** may have an inlet passage **114** of the turbine **94** which may directly receive blowdown exhaust gas from the respective single blowdown exhaust passage **38** and which may direct blowdown exhaust gas to the turbine wheel **95** of the turbine **94**. When assembled, the inlet opening **102** of the inlet passage **114** may be directly aligned with and may directly confront the first or second single blowdown port openings **88**, **90**. As a result, the inlet passage **114** and the respective single blowdown exhaust passage **38** may provide a single continuously extending passage between the housing **100** and the cylinder head **12**. The housing **100** may also have a coolant passage supply **116** and a coolant passage return **118**. The coolant passage supply **116** may have one or more coolant supply openings **120**, and the coolant passage return **118** may have one or more coolant return openings **122**. The housing **100** may further have an oil passage supply **124** and an oil passage return **126**. The oil passage supply **124** may have one or more oil supply openings **128**, and the oil passage return **126** may have one or more oil return openings **130**. The coolant and oil passages **116**, **118**, **124**, **126**, may respectively directly communicate with the coolant and oil passages **60**, **62**, **68**, **70**, of the cylinder head **12**, so that together the directly communicating passages may respectively provide a single continuously extending passage between the housing **100** and the cylinder head. Referring to FIG. **12**, the housing **100** may have an outlet passage **132** of the compressor **96** which may communicate with the charge-air cooler **24**. The outlet passage **132** may have the outlet opening **104**. And the housing **100** may have an outlet passage **134** of the turbine **94** which may, though not shown, communicate with the aftertreatment device **20** or may eventually deliver exhaust gas out of the ICE breathing system **10**.

The exhaust gas aftertreatment device **20** may be equipped on the exhaust side of the ICE **14** and may be used to help reduce exhaust emissions of the exhaust gas that passes through it. The aftertreatment device **20** may come in various types including a catalytic converter, a diesel particulate filter (DPF), a soot trap, and/or the like. The exact type used may depend on many factors including the architecture and type of the ICE **14** and the environmental regulations of the particular jurisdiction in which the ICE will be used. Referring to the illustrative embodiment of FIGS. **7-9**, the aftertreatment device **20** may be a close-coupled catalytic converter **136**. The catalytic converter **136** may have a first and second inlet pipe **138**, **140** that respectively define first and second inlet passages. The first and second inlet pipes **138**, **140** may be directly mounted to the mounting face **82** of the cylinder head **12** via flanges at the ends of the pipes and bolts **142**, and may be mounted respectively at the first and second single scavenge exhaust ports **52**, **56**; of course other mounting ways are possible. The first and second inlet passages of the first and second inlet pipes **138**, **140** may respectively directly communicate with the first and second single scavenge exhaust ports **52**, **56** of the cylinder head **12**, so that together the directly communicating passages and ports may respectively provide a single continuously extending passage between the catalytic converter **136** and the cylinder head. The first and second inlet passages of the first and second inlet pipes **138**, **140** may respectively directly receive scavenge exhaust gas from the first and second single scavenge exhaust ports **52**, **56**. Though not shown in FIGS. **7-9**, the catalytic converter **136** may also receive blowdown exhaust gas flow from the outlet passages **134** of the turbines **94**.

Still referring to FIGS. **7-9**, the catalytic converter **136** may also have a bypass pipe **144** and an outlet pipe **146**. The bypass pipe **144** may define a bypass passage which may

communicate with the EGR assembly 22. And the outlet pipe 146 may define an outlet passage which may eventually deliver exhaust gas which goes therethrough out of the ICE breathing system 10 and eventually to the atmosphere.

The EGR assembly 22 may be used to recirculate and direct a measured amount of exhaust gas expelled from the ICE 14 back to the intake side of the ICE. Depending on the embodiment and circumstances, the recirculated exhaust gas may mix with incoming air and/or air-fuel mixture and may decrease or increase the combustion temperature taking place in the ICE 14. The EGR assembly 22 may have various constructions, arrangements, and components, including a high-pressure-loop EGR assembly and a low-pressure-loop EGR assembly. In the illustrative embodiments of FIG. 1, for example, the EGR assembly 22 may include a proportional or mix valve 148, a first EGR valve 150, a second EGR valve 152, a third EGR valve 154, an EGR cooler 156, and a fourth EGR valve 158.

Still referring to FIG. 1, the mix valve 148 may be used to regulate and apportion exhaust gas flow between the first and second EGR valves 150, 152, and particularly exhaust gas flow in the form of blowdown and scavenge exhaust gas flow. The mix valve 148 may selectively permit (open) exhaust gas flow to the first and/or second EGR valves 150, 152, and may selectively prevent (close) exhaust gas flow to the first and/or second EGR valves. When permitting exhaust gas flow, the mix valve 148 may partially permit exhaust gas flow to a desired degree (partially open); that is, the mix valve can be less than fully open. The mix valve 148 may apportion any percentage amount of scavenge exhaust gas flow and blowdown exhaust gas flow therethrough and eventually to the intake side of the ICE 14; for example, a larger percentage amount of scavenge exhaust gas may be directed to the intake side than blowdown exhaust gas. As shown in FIG. 1, the mix valve 148 may communicate with and may receive exhaust gas flow from the blowdown exhaust passages and the scavenge exhaust passages. In some embodiments, the mix valve 148 may be used to control turbocharger boost; for example, the mix valve can be opened to receive blowdown exhaust gas from the blowdown exhaust passages, taking away blowdown exhaust gas that may otherwise be provided to the turbocharger, and thus reducing turbocharger boost. In some embodiments, the mix valve 148 need not be provided whereby the first and second EGR valves 150, 152 communicate with the blowdown and scavenge exhaust passages.

The first or blowdown EGR valve 150 may be used to regulate blowdown exhaust gas flow from the mix valve 148. The first EGR valve 150 may selectively permit (open) blowdown exhaust gas flow to the EGR cooler 156, and may selectively prevent (close) blowdown exhaust gas flow to the EGR cooler. The second or scavenge EGR valve 152 may be used to regulate scavenge exhaust gas flow from the mix valve 148. The second EGR valve 152 may selectively permit (open) scavenge exhaust gas flow to the EGR cooler 156, and may selectively prevent (close) scavenge exhaust gas flow to the EGR cooler. The third EGR valve 154 may be used to regulate exhaust gas flow from the turbines 94 of the turbochargers 16, 18. The third EGR valve 154 may selectively permit (open) exhaust gas flow to the EGR cooler 156, and may selectively prevent (close) exhaust gas flow to the EGR cooler. The first and second EGR valves 150, 152 may be a part of a high-pressure-loop EGR assembly, and the third EGR valve 154 may be a part of a low-pressure-loop EGR assembly.

The EGR cooler 156 may be a heat exchanger that lowers the temperature of exhaust gas that passes through it. The EGR cooler 156 may come in various types including an

in-line type, a u-shaped type, or another type. The exact type used may depend on many factors including the architecture and type of the ICE 14, and the construction and arrangement of other components of the EGR assembly 22. As shown in FIG. 1, the EGR cooler 156 may communicate with the first, second, third, and fourth EGR valves 150, 152, 154, 158.

The fourth EGR valve 158 may be used to regulate exhaust gas flow between the intake ports of the cylinder head 12 and the compressors 96 of the turbochargers 16, 18. The fourth EGR valve 158 may selectively permit (open) exhaust gas flow to the cylinder head 12 or the compressors 96, and may selectively prevent (close) exhaust gas flow to the cylinder head or the compressors. The fourth EGR valve 158 may communicate with and may receive exhaust gas flow from the EGR cooler 156.

In the illustrative embodiment of FIGS. 7-9, the EGR cooler 156 and the fourth EGR valve 158 may be integrated and structurally combined into a single component 160 (represented by phantom rectangle in FIG. 1)—as opposed to being two separate components, though this is an option. In some cases, the single or common structure of the EGR cooler 156 and fourth EGR valve 158 may provide packaging and assembly advantages. The integrated component 160 may receive scavenge exhaust gas flow directly from the bypass passage of the bypass pipe 144, and/or may receive blowdown exhaust gas flow exiting the outlet passages 134 of outlet pipes 166 of the turbines 94. The integrated component 160 may then direct exhaust gas flow via outlet pipes 162 and its associated outlet passages to inlet pipes 164 and its associated inlet passages of the compressors 96, may direct exhaust gas flow to the charge-air cooler 24, and/or may direct exhaust gas flow to the intake ports of the cylinder head 12. The integrated component 160 may have a coolant passage supply and return via coolant pipes 166 in order to provide coolant flow. The coolant pipes 166 may communicate with coolant passages of the cylinder head 12.

In other embodiments, the EGR assembly 22, or components thereof, may be directly mounted to the cylinder head 12. For example, referring to FIG. 2, the integrated component 160 may be mounted by bolting to a bottom wall 168 of the cylinder head 12 (shown in phantom). The integrated component 160 may be positioned so as not to structurally obstruct or interfere with the cylinder block sitting below the cylinder head 12 when the ICE 14 is assembled. In this embodiment, the integrated component 160 may communicate directly with, and may directly receive scavenge exhaust gas from, the scavenge exhaust ports of the cylinder head 12. In a similar embodiment, the integrated component 160 may also include the mix valve 148, may be mounted by bolting to the bottom wall 168, and may communicate directly with, and may directly receive exhaust gas from, both the scavenge exhaust ports and the blowdown exhaust ports of the cylinder head 12.

The EGR assembly 22 may have more, less, and/or different components than shown and described; for example, the EGR assembly need not have all of the valves shown in FIG. 1 and instead could have a 3- or 4-way valve located upstream of the EGR cooler 156 and performing the functions of one or more of the described EGR valves 150, 152, 154, 158.

The charge-air cooler 24 may be used to lower the temperature of (cool) fluid, such as air and/or recirculated exhaust gas, that passes through it. The charge-air cooler 24 may come in various types; the exact type used depends on many factors including the architecture and type of the ICE 14 and on the construction and arrangement of other components of the ICE breathing system 10. Referring to FIG. 1, the charge-air cooler 24 may receive fluid flow from the compressors 96,

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and may then direct fluid flow to the intake ports of the cylinder head 12. In the illustrative embodiment of FIGS. 7-9, the charge-air cooler 24 may be integrated with the cover 92; for example, the charge-air cooler may be mounted directly to the top side or bottom side of the cover by bolting. The integrated charge-air cooler 24 may have inlet pipes 168 and their associated inlet passages that directly communicate and receive fluid flow from outlet pipes 170 and the associated outlet passages 132 of the compressors 96. In other embodiments, the charge-air cooler 24 need not be integrated with the cover 92 and instead could be a separate component unassociated with the cover.

In other embodiments, the ICE breathing system 10 may have more, less, and/or different components than shown and described. For example, one or more additional valves may be located throughout the ICE breathing system 10 in order to manage fluid flow among and between different components and passages; referring to FIG. 1, an air filter 172 may be located upstream of the compressors 96; a throttle valve 174 (shown in phantom in FIG. 1) may be located downstream of the charge-air cooler 24 and may regulate fluid flow entering the ICE 14; and another aftertreatment device may be provided in the ICE breathing system (not shown). The ICE breathing system 10 may further include the sensors and/or controllers described in the International Application No. PCT/US09/34392, and may have the components and arrangements described in the International Application No. PCT/US09/34392.

The above description of embodiments of the invention is merely exemplary in nature and, thus, variations thereof are not to be regarded as a departure from the spirit and scope of the invention.

What is claimed is:

1. A product comprising:

a cylinder head (12) having at least two cylinders (26), the at least two cylinders (26) each having a blowdown exhaust passage (34, 36) and a scavenge exhaust passage (40, 42, 44, 46), the blowdown exhaust passages (34, 36) converging toward each other and communicating with each other in the cylinder head (12), the cylinder head (12) also having at least one other passage; and

a turbocharger (16, 18) having an inlet passage (114) directly communicating with the converged blowdown exhaust passage (38) and directly receiving exhaust gas from the converged blowdown exhaust passage (38), the turbocharger (16, 18) also having at least one other passage directly communicating with the at least one other passage of the cylinder head (12) wherein the turbocharger (16, 18) includes a turbine (94), a compressor (96), and a housing (100), the inlet passage (114) being an inlet passage (114) of the turbine (94), the turbine (94) including a turbine wheel (95), the compressor (96) including a compressor wheel (97), the housing (100) being mounted directly to the cylinder head (12), the housing (100) covering a portion of the turbine wheel (95) with the other portion of the turbine wheel (95) being housed by a cavity (76) located in the cylinder head (12), and the housing (100) covering a portion of the compressor wheel (97) with the other portion of the compressor wheel (97) being housed by the cavity (76).

2. A product as set forth in claim 1 wherein the scavenge exhaust passages (40, 42, 44, 46) converge toward each other and communicate with each other in the cylinder head (12), the product further comprising an aftertreatment device (20) having an inlet passage directly communicating with the con-

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verged scavenge exhaust passages (52, 56) and directly receiving exhaust gas from the converged scavenge exhaust passages (52, 56).

3. A product as set forth in claim 2 further comprising an exhaust gas recirculation assembly (22) having an inlet passage directly communicating with a bypass passage of the aftertreatment device (20), the exhaust gas recirculation assembly (22) also having an outlet passage communicating with an inlet passage of a compressor (96) of the turbocharger (16, 18).

4. A product as set forth in claim 1 wherein the cylinder head (12) has at least four cylinders (26), the at least four cylinders (26) each having a blowdown exhaust passage (34, 36) and a scavenge exhaust port (40, 42, 44, 46), the blowdown exhaust passages (34, 36) of one neighboring pair of cylinders (26) converging toward each other and communicating with each other in the cylinder head (12), the blowdown exhaust passages (34, 36) of the other neighboring pair of cylinders (26) converging toward each other and communicating with each other in the cylinder head (12), the inlet passage (114) of the turbocharger (16, 18) directly communicating with one of the converged blowdown exhaust passages (38), the product further comprising a second turbocharger (16, 18) having a second inlet passage (114) directly communicating with the other of the converged blowdown exhaust passages (38) and directly receiving exhaust gas therefrom.

5. A product as set forth in claim 1 wherein the converged blowdown exhaust passage (38) has a single blowdown port opening (88, 90) that exits the cylinder head (12), the turbocharger (16, 18) including a shaft assembly (98), the inlet passage (114) having an inlet opening (102) that exits in the housing (100), the shaft assembly (98) connecting the turbine and compressor wheels and being enclosed within the housing (100), the inlet opening (102) and the single blowdown port opening (88, 90) being directly aligned such that the inlet passage (114) and the converged blowdown exhaust passage (38) together provide a substantially continuous passage extending between the turbocharger (16, 18) and the cylinder head (12).

6. A product as set forth in claim 1 wherein the at least one passage of the turbocharger (16, 18) includes a coolant passage (116, 118) and an oil passage (124, 126), the at least one passage of the cylinder head (12) includes a coolant passage (60, 62) and an oil passage (68, 70), the coolant passages (116, 118, 60, 62) being directly aligned such that together they provide a substantially continuous passage extending between the turbocharger (16, 18) and the cylinder head (12), and the oil passages (124, 126, 68, 70) being directly aligned such that together they provide a substantially continuous passage extending between the turbocharger (16, 18) and the cylinder head (12).

7. A product as set forth in claim 1 further comprising an exhaust gas recirculation assembly (22) mounted directly to the cylinder head (12) and having an inlet passage directly communicating with the scavenge exhaust passages (40, 42, 44, 46), the exhaust gas recirculation (22) assembly also having an outlet passage communicating with an inlet passage of a compressor (96) of the turbocharger (16, 18).

8. A product as set forth in claim 1 further comprising a charge-air cooler (24) directly mounted to a cover (92) of the cylinder head (12) and having an inlet passage directly communicating with an outlet passage (132) of a compressor (96) of the turbocharger (16, 18).

9. A product comprising:

an internal combustion engine breathing system (10) comprising:

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- a turbocharger (16, 18) including a turbine (94) and a compressor (96), the turbine (94) having an inlet passage (114) directly communicating with a blowdown exhaust passage (34, 36, 38) of a cylinder head (12) of an internal combustion engine (14) and directly receiving exhaust gas from the blowdown exhaust passage (34, 36, 38), the turbocharger (16, 18) having a plurality of passages that directly communicate with respective ports or passages of the cylinder head (12);
- an aftertreatment device (20) communicating with a scavenge exhaust passage (40, 42, 44, 46) of the cylinder head (12) and receiving exhaust gas from the scavenge exhaust passage (40, 42, 44, 46);
- an exhaust gas recirculation assembly (22) communicating with the scavenge exhaust passage (40, 42, 44, 46) of the cylinder head (12) and receiving exhaust gas from the scavenge exhaust passage (40, 42, 44, 46), the exhaust gas recirculation assembly (22) also communicating with the compressor (96) of the turbocharger (16, 18); and
- a charge-air cooler (24) mounted to a cover (92) of the cylinder head (12) and communicating with the compressor (96) of the turbocharger (16, 18) wherein the turbocharger (16, 18) includes a housing (100) mounted directly to the cylinder head (12), the turbine (94) includes a turbine wheel (95), and the compressor (96) includes a compressor wheel (97), the housing (100) covering a portion of the turbine wheel (95) with the other portion of the turbine wheel being housed by a cavity (76) located in the cylinder head (12), and the housing (100) covering a portion of the compressor wheel (97) with the other portion of the compressor wheel being housed by the cavity (76).
10. A product as set forth in claim 9 wherein the turbocharger (16, 18) includes a shaft assembly (98) connecting the

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turbine and compressor wheels and being enclosed within the housing (100), the housing (100) having a mounting face (112) mounted directly to the cylinder head (12) and directly opposing a portion of the cylinder head (12).

11. A product as set forth in claim 9 wherein the plurality of passages of the turbocharger (16, 18) includes a coolant passage (116, 118) and an oil passage (124, 126), the coolant passage (116, 118) of the turbocharger (16, 18) being directly aligned with a coolant passage (60, 62) of the cylinder head (12) such that together they provide a substantially continuous passage extending between the turbocharger (16, 18) and the cylinder head (12), and the oil passage (124, 126) of the turbocharger (16, 18) being directly aligned with an oil passage (68, 70) of the cylinder head (12) such that together they provide a substantially continuous passage extending between the turbocharger (16, 18) and the cylinder head (12).

12. A product comprising:

a cylinder head (12) having at least one cylinder (26), the at least one cylinder (26) having a blowdown exhaust passage (38) and a scavenge exhaust passage (48), with a cavity (76) located in the cylinder head (12); and

a turbocharger (16, 18) having an inlet passage (114) directly communicating with the blowdown exhaust passage (38) and directly receiving exhaust gas from the blowdown exhaust passage (38) wherein the turbocharger (16, 18) includes a turbine (94), a compressor (96), and a housing (100), that is semi-circular in shape, the inlet passage (114) being an inlet passage (114) of the turbine (94), the housing (100) being directly adjacent to the cylinder head (12), the housing (100) housing a first part of the turbocharger (16) with a second part of the turbocharger (16, 18) being housed by the cavity (76).

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